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LIFAC Sorbent Injection Desulfurization Demonstration Project

Presented By

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INTRODUCTION

In December 1990, the U.S. Department of Energy selected 13 projects for funding under the Federal Clean Coal Technology Program (Round III). One of the projects selected was the project sponsored by LIFAC North America, (LIFAC NA), titled "LIFAC Sorbent Injection Desulfurization Demonstration Project." The host site for this $17 million, three-phase project is Richmond Power and Light's Whitewater Valley Unit No. 2 in Richmond, Indiana. The LIFAC technology uses upper-furnace limestone injection with patented humidification of the flue gas to remove 75-80% of the sulfur dioxide (SO_2) in the flue gas.

In November 1990, after a ten (10) month negotiation period, LIFAC NA and the U.S. DOE entered into a Cooperative Agreement for the design, construction, and demonstration of the LIFAC system. This report is the first Technical Progress Report covering the period from project execution through the end of December 1990. Due to the power plant's planned outage schedule, and the time needed for engineering, design and procurement of critical equipment, DOE and LIFAC NA agreed to execute the Design Phase of the project in August 1990, with DOE funding contingent upon final signing of the Cooperative Agreement.

BACKGROUND

Project Team

The LIFAC demonstration at Whitewater Valley Unit No. 2 is being conducted by LIFAC North America, a joint venture partnership between:

- ICF Kaiser Engineers - A U.S. company based in Oakland, California, and a subsidiary of ICF International (ICF) based in Fairfax, Virginia.

- Tampella Power Corp. - A U.S. subsidiary of a large diversified international company, Tampella Corp., based in Tampere, Finland and the original developer of the LIFAC technology.

LIFAC NA is responsible for the overall administration of the project and for providing the 50 percent matching funds. Except for project administration, however, most of the actual work is being performed by the two parent firms under service agreements with LIFAC NA. Both parent firms work closely with Richmond Power and Light and the other project team members, including ICF Resources, the Electric Power Research Institute (EPRI), Indiana Corporation for Science and Technology (ICS&T), Peabody Coal Company, and Black Beauty Coal Company. LIFAC NA is having ICF Kaiser Engineers manage the demonstration project out of its Pittsburgh office, which provides excellent access to the DOE representatives of the Pittsburgh Energy Technology Center. Figure 1 shows the management structure being used throughout the three phases of the project.

LIFAC NA administers the project through a Management Committee that decides the overall policies, budgets, and schedules. All funding sources, invoicing, and information flows to LIFAC NA where the managing partners ensure that the project, funding and expenditures are consistent and in-line with the established policies, budgets, schedules and procedures.

Process Development

In 1983, Finland enacted acid rain legislation which applied limits on SO_2 emissions sufficient to require that flue gas desulfurization systems have the capability to remove about eighty percent (80%) of the sulfur dioxide in the flue gas. This level could be met by conventional scrubbers, but could not be met by then available sorbent injection technology. Therefore, Tampella began developing an alternative system which resulted in the LIFAC process.

Initially, development included laboratory scale and pilot plant tests. Full-scale limestone injection tests were conducted at Tampella's Inkeroinen facility, a 160 MWe coal-fired boiler using high-ash, low-sulfur Polish coal. At Ca:S ratios of 3.1, sulfur removal was less than 50%. Better results could have been attained using lime, but was rejected because the cost of lime is much higher than that of limestone.

In-house investigations by Tampella led to an alternative approach involving humidification in a separate vertical chamber which became known as the LIFAC Process. In cooperation with Pohjolan Voima Oy, a Finnish utility, Tampella installed a full-scale limestone injection facility on a 220 MWe coal-fired boiler located at Kristiinankaupunki. At this facility, a slipstream (5000 SCFM) containing the calcined limestone was used to test a small-scale activation reactor (2.5 MW) in which the gas was humidified. Reactor residence times of 3 to 12 seconds resulted in SO_2 removal rates of 84%. Additional LIFAC pilot-scale tests were conduced at the 8 MWe (thermal) level at the Neste Kulloo combustion laboratory to develop the relationships between the important operating and design parameters. Polish low-sulfur coal was burned to achieve 84% SO_2 removal.

In 1986, full-scale testing of LIFAC was conducted at Imatran Voima's Inkoo power plant on a 250 MWe utility boiler. An activation chamber was built to treat a flue gas stream representing about 70 MWe. Even though the boiler was 250 Mwe, the 70 Mwe stream represented about one-half of the flue gas feeding one of the plant's two EPSs (i.e., each ESP receives a 125 MWe gas stream). This boiler used a 1.5% sulfur coal and sulfur removal was initially 61%. By late 1987, SO_2 removal rates had improved to 76%. In 1988, a LIFAC activation reactor was added to treat an additional 125 MWe -- i.e., an entire flue gas/ESP stream-worth of flue gas from this same boiler. This newer activation reactor is achieving 75-80% SO_2 removal with Ca:S ratios between 2.0:1 and 2.5:1. In 1988, the first tests using high-sulfur U.S. coals were run at the pilot scale at the Neste Kulloo Research Center, using a Pittsburgh No. 8 coal containing 3% sulfur. SO_2 removal rates of 77% were achieved at a Ca:S ratio of 2:1.

This LIFAC demonstration project will be conducted on a 60 MWe boiler burning high-sulfur U.S. coals to demonstrate the commercial application of the LIFAC process to U.S. utilities.

Process Description

LIFAC combines upper-furnace limestone injection followed by post-furnace humidification in an activation reactor located between the air preheater and the ESP. The process produces a dry and stable waste product that is partially removed from the bottom of the activation reactor and partially removed at the ESP.

Finely pulverized limestone is pneumatically conveyed and injected into the upper part of the boiler. Since the temperatures at the point of injection are in the range of 1800-2000° F, the limestone ($CaCO_3$) decomposes to form lime (CaO) which is more reactive. As the lime passes through the furnace, initial desulfurization reactions take place. A portion of the SO_2 reacts with the CaO to form calcium sulfite ($CaSO_3$), part of which then oxidizes to form calcium sulfate ($CaSO_4$). Essentially all of the sulfur trioxide (SO_3) reacts with the CaO to form $CaSO_4$.

The flue gas and unreacted lime exit the boiler and pass through the air preheater. On leaving the air preheater, the gas/lime mixture enters the patented LIFAC activation reactor. In the reactor, additional sulfur dioxide capture occurs after the flue gas is humidified with a water spray. Humidification converts lime CaO to hydrated lime, $Ca(OH)_2$, which enhances further SO_2 removal. The activation reactor is designed to allow time for effective humidification of the flue gas, activation of the lime, and reaction of the SO_2 with the sorbent. All the water droplets evaporate before the flue gas leaves the activation reactor. The activation reactor is also designed specifically to minimize the potential for solids build-up on the walls of the chamber. The net effect is that at a Ca:S ratio in the range of 2:1 to 2.5:1, 75-80% of the SO_2 is removed from the flue gas.

The flue gas leaving the activation reactor then enters the existing ESP where the spent sorbent and fly ash are removed from the flue gas and sent to the disposal facilities. ESP effectiveness is also enhanced by the humidification of the flue gas. The solids collected by the ESP consist of fly ash, $CaCO_3$, $CA(OH)_2$, CaO, $CaSO_4$, and $CaSO_3$. To improve utilization of the calcium, and possibly increase SO_2 reduction to above 85%, a portion of the spent sorbent collected in the bottom of the activation reactor and/or in the ESP hoppers is recycled back into the ductwork just ahead of the activation reactor.

Process Advantages

The LIFAC technology has similarities to other sorbent injection technologies using humidification, but employs a unique patented vertical reaction chamber attached to the down-stream sections of the boiler to facilitate and control the sulfur capture and other chemical reactions. This chamber improves the overall reaction efficiency enough to allow the use of pulverized limestone rather than more expensive reagents such as lime which are often used to increase the efficiency of other sorbent injection processes.

Sorbent injection is a potentially important alternative to conventional wet lime and limestone scrubbing, and this project is another effort to test alternative sorbent injection approaches. In comparison to wet systems, LIFAC removes less sulfur dioxide - 75-80% relative to 90% or greater for conventional scrubbers - and requires more reagent material. However, if the demonstration is successful, LIFAC will offer these important advantages over wet scrubbing systems:

- LIFAC is relatively easy to retrofit to an existing boiler and requires less area than conventional wet FGD systems.

- LIFAC is less expensive to install than conventional wet FGD processes.

- LIFAC's overall costs measured on a dollar-per-ton SO_2 removed basis are less, an important advantage in a regulatory regime with trading of emission allocations.

- LIFAC produces a dry, readily disposable waste by-product versus a wet product.

- LIFAC is relatively simple to operate.

HOST SITE DESCRIPTION

The site for the LIFAC demonstration is Richmond Power and Light's Whitewater Valley 2 pulverized coal-fired power station (60 MWe), located in Richmond, Indiana. Whitewater Valley 2 began service in 1971, is a Combustion Engineering tangentially-fired boiler which uses high-sulfur bituminous coal from Western Indiana. Actual power generation produced by the unit approaches 65 megawatts. As such, it is one of the smallest existing, tangentially-fired units in the United States. The furnace is

26 feet 11 inches deep and 24 feet 8 inches wide. It has a primary and secondary superheater in addition to the back boiler. Tube sizes and spacings are designed to achieve the highest possible heat-transfer rates with the least potential for gas-side fouling. The unit also has an inherent low draft-loss characteristic because of the lack of gas turns. At full load 540,000 lbs/hr. of steam are generated. The heat input at rated capacity is 651 x 10^6 Btu per hour. The design superheater outlet pressure and temperature are 1320 psi at 955°F. The unit has a horizontal shaft basket-type air preheater. The temperature leaving the economizer is 665°F, while the flue gas temperature is 285°F. The balanced-draft unit has 12 burners.

In 1980 the unit was fitted and fully optimized with a state-of-the-art Low-NO_x Concentric Firing System (LNCFS). The LNCFS represents a very cost effective means of reducing NO_x emissions in comparison with other retrofit possibilities. The system works on the principal of directing secondary air along the sides of the furnace and creating a fuel rich zone in the center of the furnace. With the LNCFS, the excess air can be maintained below 20 percent. Additionally, the installation reduces ash accumulation on the furnace walls increasing heat absorption and reducing attemperation requirements. With the LNCFS, each corner of the furnace has a tangential windbox consisting of three coal compartments and four auxiliary air compartments. At full load with all three 593 RB pulverizers operating, primary transport air from the pulverizers amounts to 23 percent of the total combustion air. Pulverizer capacity is 26,400 lbs/hr. with 52 grind coal and 70 percent minus 200 mesh.

Whitewater Unit 2 has a Lodge Cottrell cold side precipitator which was erected with the boiler. The precipitator treats 227,000 actual cubic feet per minute of 285°F flue gas with 45,000 square feet of collection area. The unit has two mechanical fields and four electrical fields and achieves 99 percent removal efficiency (from 3.9 gr/ft^3 to 0.04 gr/ft^3). The ESP performance was optimized by Lodge Cottrell when Richmond Power and Light purchased new controllers in 1985.

Whitewater Valley Unit 2's overall efficiency of 87.47 percent at full load has shown little variation over the years. The unit's average heat rate is 10,280 Btu/Kwh. At 60 percent of full load, the unit's efficiency increases to 88.17 percent. The unit uses approximately 0.935 pounds of coal per Kwh and generates 8.51 pounds of steam per Kwh.

The primary emissions monitored at the station are SO_2 and opacity. SO_2 emissions are calculated based on the coal analysis and are limited to 6 lbs/10^6 Btu. Opacity is monitored using an in-situ meter at the ESP outlet and is limited to 20 percent. Current SO_2 emissions for the unit are approximately 4 lbs/10^6 Btu, while opacity at full load ranges from 15 to 20 percent. Opacity at low load (40MW) ranges from 3 to 5 percent. Limited testing was conducted in November of 1986 for NO_x emissions. Results from the test work indicated that NO_x emissions averaged 0.65 lbs/10^6 Btu.

Whitewater Valley 2 has several important qualities as a LIFAC demonstration site. One of these is that Whitewater Valley 2 was the site of a prior joint EPA/EPRI demonstration of LIMB sorbent injection technology. Much of the sorbent injection equipment remains on site and will be used in the LIFAC demonstration, if possible. Another advantage of the site is that Whitewater Valley is a challenging candidate for a retrofit due to the cramped conditions at the site. The plant is thus typical of many U.S. power plants which are potential sites for application of LIFAC. In addition, Whitewater Valley No. 2 boiler is small relative to its capacity; hence, it has high-temperature profiles relative to other boilers. This situation will require sorbent injection at higher points in the furnace in order to prevent deadburning of the reagent and may decrease residence times needed for sulfur removal. Whitewater Valley 2 will show LIFAC's performance under operational conditions most typical of U.S. power plants. The project will demonstrate LIFAC on high-sulfur U.S. coals and is a logical extension of the Finnish demonstration work and important for LIFAC's commercial success in the U.S.

PROJECT SCHEDULE

To demonstrate the technical viability of the LIFAC process to economically reduce sulfur emissions from the Whitewater Valley Unit No. 2, LIFAC NA is conducting a three-phase project.

Phase I: Design
Phase IIA: Long Lead Procurement
Phase IIB: Construction
Phase III: Operations

Except Phase IIA, each phase is comprised of three (3) tasks, a management and administration task, a technical task and an environmental task. The design phase began on August 8, 1990 and is scheduled to last six (6) months. Phase IIA, long lead procurement, overlaps the design phase and requires about four (4) months to complete. The construction phase will then continue for another seven (7) months, while the operations phase is scheduled to last about twenty-six (26) months. Figure 2 shows the estimated project schedule which is based on a August 8, 1990 start date and a planned outage of Whitewater Valley Unit No. 2 during March 1991.

It is during this outage that all the tie-ins and modifications to existing Unit No. 2 equipment will be made. This will require that the construction phase begin in early February, 1991 -- construction and start-up will then be completed by the end of August 1991. Operations and testing will begin in September 1991 and will continue for 26 months.

TECHNICAL PROGRESS

The work performed during this period (August-December 1990) was consistent with the Statement of Work contained in the Cooperative Agreement. During the early stages of Budget Period I, emphasis was placed on all three tasks in the Design Phase (Project Management, Engineering and Design, Environmental Monitoring) and the Long Lead Procurement task in the Construction Phase. Following is a summary of the work performed under these tasks.

Project Management (WBS 1.1.1)

During this period, most of the efforts were devoted to finalizing contractual arrangements among the project participants. These include:

- Signing the Host Site Agreement with Richmond Power and Light
- Formalizing the Joint Venture Agreements between Tampella and ICF Kaiser Engineers, including the partnership, licensing, and marketing agreements
- Completing all negotiations with DOE and signing of the Cooperative and Repayment Agreements
- Submitting for and receiving an Advanced Patent Waiver
- Assisting DOE in preparation of the Report to Congress.

Also, during this reporting period draft copies of the subcontract agreements between LIFAC NA and its four subcontractors were prepared and forwarded to the team members for review and comment. Included in the subcontract agreements were respective Scopes of Work and baseline budgets for each subcontractor.

LIFAC NA also continued negotiations with the tentative cofunders on the project including:

- Electric Power Research Institute
- Indiana Corporation for Science and Technology (ICS&T)
- Peabody Coal Company
- Black Beauty Coal Company
- LaFarge

During the period, ICS&T awarded LIFAC NA $800,000 for use during the construction phase of the project. Formal negotiations with ICS&T are scheduled for next quarter.

The project team members also participated in several technology transfer activities including exhibiting at the Pittsburgh Coal Show and at PowerGen 90. A technical paper was also presented at the Pittsburgh Coal Show.

Engineering and Design (WBS 1.1.2)

During negotiations with DOE, LIFAC NA requested permission to begin some design activities early due to the need to perform tie-in activities on Whitewater Valley Unit 2 during a planned March 1991 outage. DOE granted permission to begin this effort on August 8, 1990. If the March 1991 window had been missed, the project would have experienced at least a seven (7) month delay.

Emphasis was placed on engineering and designing all tie-in requirements for LIFAC. These included:

- Adding five additional injection ports into the boiler at a higher elevation than the existing ports.

- Designing the tie-in and by-pass ductwork, including installation of support steel and dampers, needed for installation of the Activation Reactor.

- Design of tie-in pipes and valves to the existing ESP hoppers for removal/recirculation of fly ash (spent sorbent).

- Design of tie-ins for water supply to the humidification system.

- Design of tie-ins for steam supply and condensate return lines for the flue gas reheat system.

- Detailed analysis of ID Fan operating characteristics and capabilities.

- Rerouting of pipes due to installation of new ductwork and dampers.

All tie-in requirements were identified and engineered and a detailed bid specification was issued for fabrication and installation of all tie-in requirements.

Once the March tie-in requirements were completed, the remaining preliminary design functions were initiated. Tampella developed the preliminary P&ID and material balances for the process. ICF Kaiser Engineers prepared preliminary layout drawings for the reactor and new limestone storage bin. Specifications were prepared defining the design criteria for piping, HVAC, structural steel, electrical, instrumentation, and ductwork. Tampella also prepared the bid specification for the Process Control System.

Design engineers visited the LIFAC installation at the Poplar River Power Plant in Canada to observe operations and study the unique design features of the process.

Environmental Monitoring (WBS 1.1.3)

Most of the environmental activities related to the demonstration project were completed during the pre-award negotiations phase. ICF KE submitted a draft Environmental Information Volume (EIV) to DOE on April 2, 1990 and a final on October 1, 1990. During this period ICF KE responded to DOE comments in support of the Memo-to-File obtained on the demonstration project during September. A Draft Environmental Monitoring Program was submitted to DOE on April 23, 1990 during the pre-award period. ICF KE received comments on the draft EMP from DOE on December 3, 1990.

During this reporting period, ICF KE continued to aid the host site in resolving environmental problems and to evaluate environmental developments at the Whitewater Valley facility related to the implementation of the demonstration project. ICF KE also evaluated the potential effects on the analyses presented in the EIV. These issues involved the status of air and water permits at the Whitewater facility and efforts being performed by the host site to identify or construct a disposal facility that would be capable of receiving both RP&L's existing ash waste streams and the LIFAC waste streams during the demonstration period.

RP&L received a National Pollution Discharge Elimination System (NPDES) permit on October 17, 1990 from the Indiana Department of Environmental Management (IDEM) for point source discharge from the facility.

ICF KE tracked RP&L's on-going negotiations with IDEM involving air emission limits within their draft air permit to evaluate their potential effects on the demonstration project. Resolution of this issue is of primary concern since operation of the LIFAC unit must fall under a valid IDEM permit and within the air emissions limits established in the permit conditions. As of the end of the reporting period, this issue had not been resolved.

Long Lead Procurement (WBS 1.2.1A)

During this period, all long lead items were identified and bid specifications prepared. All required equipment for the March tie-in work was ordered including:

- Dampers
- Ductwork support hangers
- Boiler tube openings
- Isolation valves

In addition, the bid specification for installation of the tie-in requirements was issued. The subcontractor will be selected in early January.

Other long lead procurement activities were identified and bid specifications started. These included:

- Reactor slag discharge conveyors
- Variable frequency controller for the ID fan
- Reactor fabrication and erection.

FUTURE PLANS

During the next period, LIFAC NA hopes to conclude negotiations and secure funding from the identified cofunders. All required reporting requirements, including cost plan/reports, milestone plan/reports, etc., will be initiated and updated monthly.

The contractor should be selected and the March tie-in requirements should be completed. Detailed design efforts should be completed and all bid specifications prepared and issued.

The Preliminary Test Plan and Environmental Monitoring Plan will be developed so the sampling and testing requirements can be incorporated into the final design.

All necessary permits or variances will be applied for so that the project can continue on schedule.